Accessing, Visualizing, and Analyzing NASA Hydrology Data in GIS: A Use Case for East Africa Drought

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Introduction

The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) is the home of NASA precipitation, hydrology, and atmospheric composition and dynamics data. We also house the Modern Era Retrospective-Analysis for Research and Applications (MERRA) data assimilation and the North American and Global Land Data Assimilation System (NLDAS and GLDAS) data products. These products are highly relevant to a wide range of research and applications in GIS. However, this extensive and precious resource is underutilized in the Geographic Information Systems (GIS) communities. The primary factors contributed to this situation include the unfamiliarity of many GIS users with the GES DISC products and the lack of functionalities of traditional GIS software packages in processing, analyzing, and visualizing NASA satellite data that are mostly raster-based with time components.

We introduce the GES DISC the precipitation/hydrology products, the currently available services of delivering GIS-enabled data products, and the on-going efforts of making our data more easily accessed and used my the GIS communities. We present a use scenario in which the GES DISC archived Tropical Rainfall Measuring Mission (TRMM) precipitation data and the NASA MODIS Normalized Vegetation Index (NDVI) data were processed and analyzed in the ArcGIS software. The use case shows how the 2010-2011 East African drought is clearly captured by the TRMM measurements; how the region's vegetation growing conditions, as depicted by NDVI, responded to the drought; and how the drought and the vegetation response can be visualized and assessed at different watersheds in GIS.

GES DISC Hydrology Data and Services

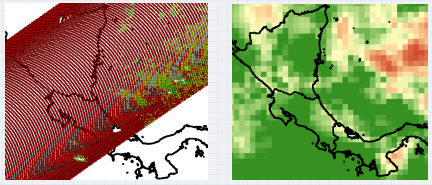
GES DISC hosts several dozens of precipitation/hydrology data products at various spatial and temporal resolutions. Some of these data products are archived in formats without geospatial reference information encoded in the data files and are not readily importable into GIS systems, such as the ArcGIS system. Several efforts have being been made in GES DISC in providing GIS-ready data. These include:

- On-the-fly GIS data format conversion
- Subsetting services
- Plug-in tools for both local and remote data
- Documents with step-by-step instructions on importing GES DISC data into GIS systems, and

- The TRMM OPeNDAP service (http://disc2.nascom.nasa.gov/opendap/ncml/)

  - On-the-fly netCDF conversion
  - Variable subsetting
  - Spatial subsetting

Figure 1 shows TRMM precipitation data subsetted and format-converted data in ArcGIS.



(a) TRMM swath data as a feature layer (b) TRMM grid data as a raster layer

Figure 1. TRMM swath and gridded data output from the OPeNDAP server

- The TRMM Online Visualization and Analysis System (TOVAS) http://disc.sci.gsfc.nasa.gov/precipitation/tovas/

The TOVAS system is a part of a larger visualization system, namely the GES-DISC Interactive Online Visualization ANd aNalysis Infrastructure (Giovanni). TOVAS system allows users to visualize GES DISC hydrology data and download them in following formats formats (Figure 2):

- HDF
- netCDF
- Ascii
- KMZ

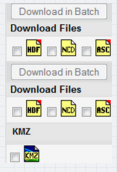


Figure 2. TOVAS download options

- The Simple Subset Wizzard (SSW) http://disc.sci.gsfc.nasa.gov/SSW/

The GES DISC SSW is a simple unified interface for

- Spatial and temporal searching
- Spatial and temporal subsetting
- Multiple data format selection

An ArcGIS plug-in tool is developed for user to connect the SSW and obtain netCDF formatted TRMM data importable Into ArcGIS (Figure3).

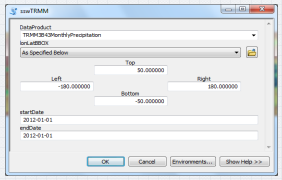


Figure 3. ArcGIS connector for SSW TRMM data

- The Open Geospatial Consortium (OGC) Web Coverage Services (WCS)

GES DISC deployed a WCS Version 1.0.0 server which enables:

- Spatial and temporal subsetting
- On-the-fly format conversion
  - HDF-EOS
  - netCDF
  - GeoTiff
- Interpolation/resampling

The WCS service also encodes multi-temporal data in one single file which allows ArcGIS users to use the Time Slider tool to visualize time series (Figure 4). An plug-in tool is available to connect ArcGIS to the WCS (Figure 5).

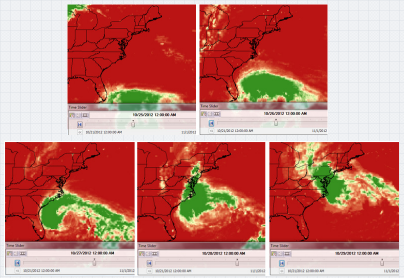


Figure 4. Hurricane Sandy's movement captured by TRMM Precipitation data

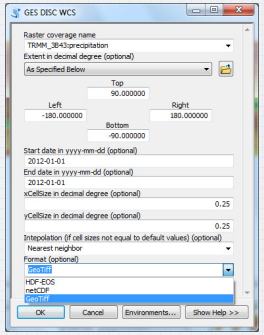
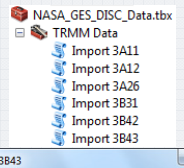


Figure 5. Plug-in for GES DISC WCS connector



- Plug-ins and instructions for data not directly importable or georeferenceable in ArcGIS
  - Direct ftp/http download s result in originally archived data file
  - Generic binary and native HDF formatted data not importable into GIS
  - Plug-in tools available for TRMM native HDF formatted data (Figure 6)
  - More plug-ins being developed for additional data products and formats
  - Instructions of ArcGIS importing steps created for most data types
  - Head files created for binary data files

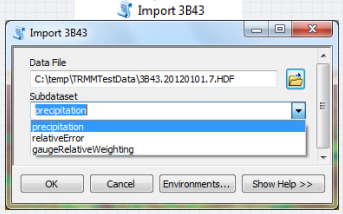


Figure 6. Plug-ins for native HDF formatted TRMM data

Visualizing and Analyzing the East Africa Drought

From the late spring of 2010 to the summer of 2011, the Horn of Africa suffered a severe and prolonged drought not seen in decades. The drought caused more than 10 million people in need for food and clean water in Ethiopia, Somalia, and Kenya. The precipitation deficit was well captured by the TRMM data. We used ArcGIS to map and visualize watershed level precipitation anomaly, as compared to long term mean, and the response of vegetation, as shown in the MODIS NDVI images, to the water deficit.

- Data
  - Watershed boundary, obtained from the Hydro1K Basins dataset prepared by the USGS Land Processes Distributed Active Archive Center (LP DAAC)
  - TRMM daily precipitation data
  - MODIS 16-day composite NDVI data, obtained from the LP DAAC (MYD13C1 L3)
- Method
  - Watershed data dissolved to level 3 water basins
  - TRMM data composited to 16-day total precipitation and resampled to 0.05-degree resolution
  - Time series of Precipitation and NDVI constructed from July 2002 to December 2011
  - Zonal statistics performed to obtain mean NDVI and precipitation for each water basin
  - Long term mean of precipitation and NDVI computed
  - Standard anomalies of each 16-day period computed:

    $a=(x-m)/s$

    a: standardized anomaly,

    m: long term mean (between 2002 and 2011)

    s: standard deviation to the long term mean

    x: precipitation or NDVI value for a given 16-day period
  - Pearson momentum correlation analyses performed

- Results and analyses
  - Time series precipitation anomaly maps show the spatiotemporal patterns of water deficiencies
  - Vegetation anomaly maps shows vegetation responses to the drought (Figures 7, 8, and 9).
  - 44 among 55 water basins exhibit statistically significant precipitation/vegetation correlation (t-test at 0.95 confidence level)
  - All water basins exhibit statistically significant precipitation/vegetation correlation when one and two 6-day period lags are applied to vegetation, indicating that the vegetation in this area generally responds to precipitation within about two to four weeks (Figure 10).

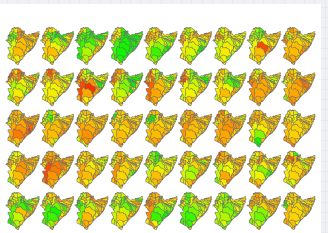


Figure 7. Spatiotemporal patterns precipitation anomalies
The plots in each figure are ordered from left to right and top to bottom. The first plot is for the period starting on 2010-01-09 and the last on 2011-12-11.

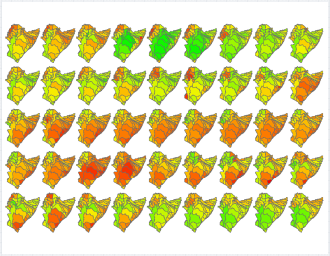


Figure 8. Spatiotemporal patterns of NDVI anomalies
The plots in each figure are ordered from left to right and top to bottom. The first plotsis for the period starting on 2010-01-09 and the last on 2011-12-11.

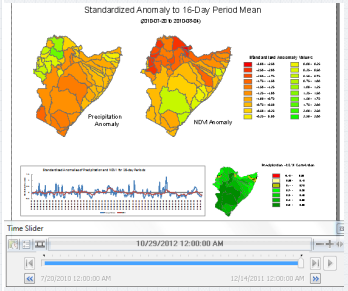


Figure 9. Visualizing precipitation/NDVI time series using ArcGIS Time Slider

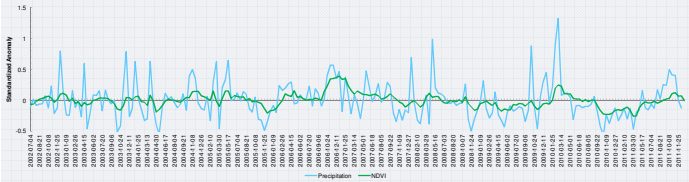


Figure 10. Standardized anomalies of precipitation and NDVI for the entire study area, with NDVI lagging one 16-day period

Summary and Future Work

- GES DISC hydrology and other data products are relevant to a range of GIS research and applications such as drought mapping/monitoring and vegetation analysis at various natural areas and/or administrative regions.
- The majority of GES DISC data are GIS-ready through various GES DISC services. The major GIS-ready data format is the CF-netCDF and version 4 HDF based HDF-EOS format.
- The ArcGIS plug-in tools facilitate data usabilities in GIS communities.
- We will continue to work on developing services and tools to enable more easy and efficient use of our data products in GIS. The following outlines some of our future efforts:
  - Make all our data available in CF-netCDF formats.
  - Make some of our data products, especially hydrology data, available in GeoTiff format.
  - Develop more plug-ins tools for data that are not currently importable to ArcGIS.
  - Develop additional remote data connectors to enable direct import of our data into ArcGIS, with spatial and temporal subsetting capabilities.
  - Develop more collaborations with users and vendors of the GIS communities.